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Research Article

Revolutionizing Automotive Workwear: A User-Centric Approach to Design Adaptive and Safe Coverall Uniforms for Mechanics in Challenging Environments

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Abstract

This research systematically explores the development of winter-oriented coverall work uniforms tailored to the specific needs of automotive mechanics. Analyzing dimensional patterns from six prominent Korean manufacturers reveals the necessity for meticulous sizing considerations and dimensional allowances, crucial for facilitating ease of movement during intricate automotive repair activities. Leveraging Apparel CAD software, differences between front and back panels are scrutinized, leading to the creation of the first-phase experimental uniform. Designed to address contamination susceptibility and prolonged drying times, this uniform is refined through on-site suitability interviews with mechanics. The final coverall work uniform emerges as a user-centric solution, providing adaptive features and enhanced safety for automotive professionals in challenging winter environments. This study not only contributes to the field of user-centric workwear design but also has transformative implications for automotive workwear in challenging conditions. By merging theoretical analyses with practical insights, it lays a robust foundation for future endeavors in tailored workwear solutions, emphasizing the crucial intersection of user satisfaction, safety, and functionality.

Keywords: Automobile mechanic; Coverall work uniform; Functional design; User-centric approach; Workwear design

Introduction

Workwear stands as a crucial shield against external elements while facilitating optimal task performance. The delicate balance between protective features and mobility is often challenged, especially as advancements in protection can lead to a reduction in mobility [1]. Recognizing this challenge, pattern and design considerations become paramount in ensuring work uniforms strike the right equilibrium.

In the realm of automotive maintenance, where tasks unfold outdoors amidst varying climates, the impact of environmental factors on individuals cannot be overstated. The demand for safe guarding against these external elements is amplified in automotive maintenance work. Beyond mere functionality, automotive maintenance uniforms must embody design elements that not only ensure efficiency and bodily protection but also contribute to the wearer's comfort, self-expression, and professional pride [2].

While existing research has predominantly focused on coverall uniforms for automotive maintenance during the spring and fall seasons, there is a conspicuous gap in addressing the specific needs of the winter season. Although coverall uniforms excel in insulation, their current designs cater primarily to the demands of spring and fall, leaving a void in the provision of winter-specific functionality.

This study represents the culminating phase in the comprehensive research journey aimed at developing a winter-specific coverall work uniform tailored explicitly for automotive maintenance personnel. Grounded in a meticulous analysis of the available winter work uniforms in the domestic Korean market, this research spans various perspectives. Through the synthesis of data-driven pattern and design development, the goal is to craft a coverall work uniform that is not only responsive to the field's demands but also versatile enough to meet diverse needs. In doing so, this development seeks to elevate the safety and work efficiency standards for automotive maintenance personnel, ensuring they are well-equipped to navigate the challenges posed by winter conditions.

Method

The methodology employed in this study is geared towards a comprehensive analysis of winter coverall automotive maintenance uniforms from six domestic companies. The objective is to delve into the intricacies of these patterns, iteratively design enhanced patterns, and eventually materialize prototypes. After prototype creation, modifications and refinements will be iteratively implemented based on insights gathered through interviews with field personnel, ensuring the practical viability of the developed winter-specific coverall automotive maintenance uniform.

Selection and pattern analysis of Korean winter-specific coverall work uniform

Winter-specific coverall work uniforms were procured from six domestic companies, uniformly sized at XL. These acquired uniforms underwent meticulous disassembly, with each component transferred onto paper patterns. These patterns were further digitized, and employing the YUKA CAD apparel program, adjustments such as centerline marking, and left-right line balance were implemented (Figure 1).

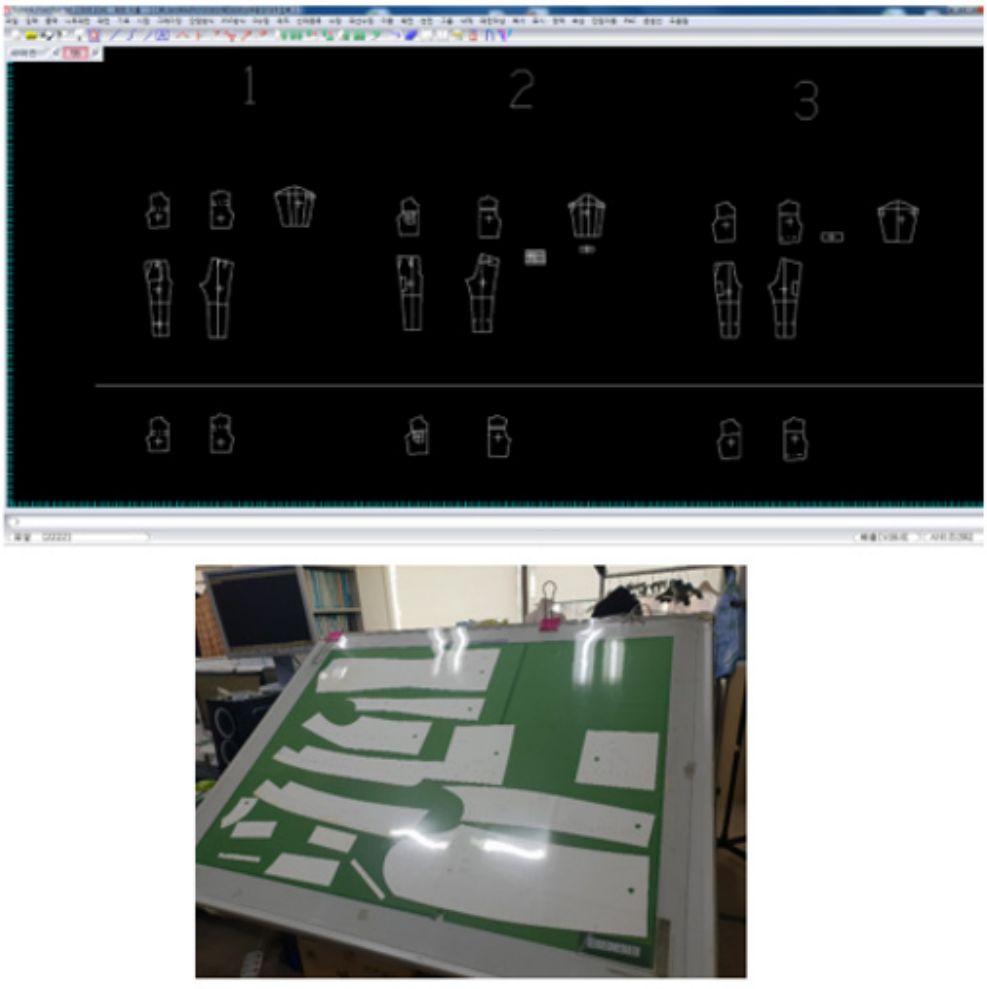


Figure 1: Digitizing in coverall patterns.

Precise measurements of each component from every company's work uniform were obtained through CAD software, forming the basis for comprehensive comparison. The digitized patterns were meticulously aligned along the centerline, facilitating an in-depth analysis of size and angle variations among the work uniforms and their individual components.

Experimental coverall works uniform pattern development and design

This phase involved the creation of two sets of work uniforms, collectively constituting an improved winter-specific coverall work uniform tailored for auto mechanics. The initial set, denoted as the '1st Experimental Work Uniform,' drew inspiration from previous research on Korean auto mechanics' coverall work uniforms and patterns from the 3rd work attire uniform [3]. Building upon wear evaluation results and insights from other work uniforms, adjustments were made to enhance flexibility. Calculations for the dimensions of each work uniform part, accounting for additional space for movement, were derived through a meticulous comparison of pattern dimensions obtained via digitization and standard dimensions of Korean men in their 20s.

Additionally, a survey of auto mechanics' work uniform preferences, conducted in a previous study [3], guided the incorporation of design enhancements, encompassing materials, colors, and details, into the initial work uniform. Subsequent interviews with auto mechanics played a pivotal role in validating the practical suitability of the 1st experimental work uniform. Insights gathered from these interviews facilitated further refinements, culminating in the development of the final coverall work uniform tailored specifically for the winter season.

Field suitability interviews

To validate the efficacy of the developed coverall, work uniform pattern, crafted through meticulous pattern analysis and leveraging insights from previous research, an experimental coverall work uniform was fabricated. Subsequently, comprehensive interviews were conducted with field practitioners to ascertain the suitability of the designed coverall work uniform for auto mechanics in their actual work environments.

Participant selection: A participant closely mirroring the average body dimensions of 20-year-old Korean males, as per the 2015 7th Korean Anthropometric Survey by the Korea Agency for Technology and Standards (KATS), was selected. The chosen participant met the stipulated evaluation criteria, aligning with the following dimensions (Table 1).

Table 1: Participant information (Shown in: Cm, Kg).

Item	Age	Height		Weight		Career	Main work
Size Korea	20-29	M.	173.95	M.	72.44	7 years	Oil change and comprehensive maintenance
		S.D.	5.72	S.D.	12.13		
		Range	171.09 – 176.80	Range	66.37 – 78.50		
Participant	29	175		75			

Field suitability interview questions: In-depth field suitability interview was conducted with an active mechanic, delving into various aspects such as the compatibility of the experimental work uniform with the work environment, its visual appeal, and its functional attributes pertinent to the mechanics' tasks.

The interviews, spanning 2 hours, took place at a maintenance facility in the Gyeonggi region, considering the participant's availability and location. Recorded with explicit consent, the interview content was employed for data collection, providing valuable insights into the direction of design development. Additionally, an expert group comprising five professionals in the field of apparel design guided the development direction for the work uniform based on interview content and validated its feasibility.

Preceding the interviews, comprehensive guidelines were prepared, encompassing inquiries related to the maintenance work environment, the fit and comfort of the work uniform, and various aspects of work uniform design, including colors, materials, details, and accessories. To assess functional aspects, a participant was presented with descriptions of ten major maintenance actions derived from a prior study [3]. The participant was then prompted to perform each action at least three times, with subsequent queries addressing any discomfort or issues encountered during the actions and focusing on the involved body areas. The overarching aim was to gather empirical feedback from a mechanic, enabling the identification of areas for pattern and design improvements in the experimental work uniform.

Research Findings

Pattern analysis of Korean winter-specific coverall work uniform for automotive mechanics

Pattern dimension comparisons: Utilizing the YUKA CAD software, we meticulously measured the dimensions of each component of the XL-sized work uniform patterns from six distinct sets (Table 2). Notably, the overall neck circumference exhibited minimal variation among the sets, with the 3rd (3.25 cm) and 4th (3.07 cm) sets showcasing the least difference between front and back neck circumferences. Conversely, the 2nd (8.85 cm) and 5th (11.66 cm) sets demonstrated a substantial disparity in these measurements.

Table 2: Detailed pattern dimensions of XL-sized work uniforms from six different sets.

N	FN	BN	TNC	CFL	CBL	AFC	AB	AF	AB	AC	SL	WAF	WAB
1	17.1	11.75	28.85	40.73	50.56	48.44	55	31.57	28.62	60.19	18.1	27.24	29.59
2	18.3	9.45	27.75	43.93	55.25	46.07	49.6	29.78	28.67	58.45	18.1	27.1	27.78
3	16.1	12.85	28.95	47.4	55.88	50.18	58.24	32.3	29.56	61.86	18.92	27	31.7
4	15.55	12.48	28.03	43.95	54.18	54.4	56.44	30.68	32.98	63.66	19.53	27.58	29.28
5	19.75	8.09	27.84	40.95	52.39	47.66	53.9	33.51	29.55	63.06	20.15	27.8	30.15
6	16.9	11.18	28.08	45.89	55.12	46.62	52.92	29.6	28.26	57.86	18	28.3	30.8
M	17.3	11	28.3	43.8	53.9	49	54.4	31.2	29.6	60.8	18.8	27.5	29.9
SD	1.53	1.85	0.52	2.64	2.04	2.95	2.99	1.52	1.73	2.41	0.89	0.49	1.35

N=Number; FN=Front Neck; BN=Back Neck; TNC=Total Neck Conference; CFL=Center Front Length; CBL=Center Back Length; AFC=Across Front Chest; AC=Across Back; AF=Arnhole Front; AB=Armhole Back; AC=Armhole Circumference; SL=Shoulder Length; WAF=Waist Arc Front; WAB=Waist Arc Back; M=Mean; SD= Standard Deviation.

N	FCD	BCD	PL	BCL	BS	CH	BHSR	BHP	BHS	BHPR	Collar Height	Hood Length
1	32.25	46.58	109.28	11.46	57.69	11.2	37.05	45	19	-	8.5	28.5
2	29.95	46.58	106.28	14.54	51.72	12.67	28.5	47.5	19.5	24	8	29
3	36.2	46.69	107.85	15.7	57.7	10.28	37	48	18	22	9.5	31
4	29.26	42.54	104.7	16	56.75	13.88	38.5	49.3	18	26	7	30.5
5	32.62	45.65	100.12	16	54.93	14.81	38	46	18	22	7	28.5
6	27.31	43.12	107	14.09	53.85	10.72	23	51	-	28	9	29
M	31.3	45.2	105.9	14.63	55.44	12.26	33.75	47.8	18.5	24.4	8.17	29.42
SD	3.12	1.88	3.21	1.75	2.39	1.83	6.46	2.18	0.71	2.61	1.03	1.07

N= Number; FCD=Front Crotch Depth; BCD=Back Crotch Depth; PL=Pant Length; BCL=Back Crotch Length; BS=Biceps for Sleeve; CH=Cap Heigth; BHSR=Bottom Hem Width of Sleeve (Rib finish); BHP=Bottom Hem of Pants; BHS=Bottom Hem Sleeve; BHPR=Bottom Hem Width of Pants (Rib finish); CH=Collar Height; HL=Hood Length; M=Mean; SD=Standard Deviation.

The front and back center lengths of the 3rd work uniform (47.4 cm, 55.88 cm) surpassed those of the other uniforms. Examining front-back circumferences, the 3rd (61.86 cm), 4th (63.66 cm), and 5th (63.06 cm) work uniforms exceeded the average dimensions. The 3rd work uniform boasted the widest sleeve width at 57.7 cm and the lowest sleeve height at 10.28 cm. Shoulder lengths were also above average for the 3rd (18.92 cm), 4th (19.53 cm), and 5th (20.15 cm) work uniforms.

In the realm of waist width, the 3rd work uniform displayed the most significant difference between front and back waist widths, with a margin of 4.7 cm. Regarding rise length, the 3rd work uniform showcased a longer front rise length of 36.2 cm and a back rise length of 46.69 cm compared to its counterparts. The 1st work uniform stood out with the longest pant length, measuring 32.25 cm.

Dimensional allowances by section

In this segment, we undertook a comprehensive analysis of the dimensional allowances for six distinct winter coverall work uniforms available in the Korean market. The calculation involved measuring the variation between the pattern dimensions of these uniforms and the established average standard dimensions for 20-year-old males (Table 3).

Table 3: Dimensional allowances by section (Unit: cm, Young Audlt Size in Korea, 2015 standard).

Average Size	NC	CFL	CBL	ACF	AB	WC	CL	SL	AC
	37.47	36.93	43.95	37.28	41.4	81.25	73.25	13.67	44.78

N	NC (Ease)	CFL (ease)	CBL (ease)	ACF (ease)	AB (ease)	WC (ease)	CL (ease)	SL (ease)	AC (ease)
1	57.70 (20.23)	40.73 (3.8)	50.56 (6.61)	48.44 (11.16)	55 (13.6)	113.66 (32.41)	78.83 (5.58)	18.1 (4.43)	60.19 (15.41)

2	55.5 (18.03)	43.93 (7)	55.25 (11.3)	46.7 (9.42)	49.6 (8.2)	109.76 (28.51)	76.53 (3.28)	18.1 (4.43)	58.45 (13.67)
3	57.9 (20.43)	47.4 (10.47)	55.88 (11.93)	50.18 (12.6)	58.24 (16.84)	117.4 (36.15)	82.89 (9.64)	18.92 (5.25)	61.86 (17.08)
4	56.06 (18.59)	43.95 (7.02)	54.18 (10.23)	54.4 (17.12)	56.44 (15.04)	113.72 (32.47)	71.8 (-1.45)	19.53 (5.86)	63.66 (18.88)
5	55.68 (18.21)	40.95 (4.02)	52.39 (8.44)	47.66 (10.38)	53.9 (12.5)	115.9 (34.65)	78.27 (5.02)	20.15 (6.48)	63.06 (18.28)
6	56.16 (18.69)	45.89 (8.96)	55.12 (11.17)	46.62 (9.34)	52.92 (11.52)	118.2 (36.95)	70.43 (-2.82)	18 (4.33)	57.86 (13.08)
M	56.5 (19.03)	43.8 (6.88)	53.9 (9.95)	49 (11.72)	54.4 (12.95)	114.8 (33.52)	76.5 (3.21)	18.8 (5.13)	60.8 (16.07)

N= Uniform Number; NC=Neck Circumference; CFL=Center Front Length; CBL=Center Back Length; ACF=Across Chest Front; AB=Across Back; WC=Waist Circumference; CL=Crotch Length; SL=Shoulder Length; AC=Armhole Circumference; M=Mean

Average allowances by section for winter coverall work uniforms were determined as follows: neck circumference 19.03 cm, front center length 6.88 cm, back center length 9.95 cm, waist circumference 33.52 cm, rise length 3.21 cm, shoulder length 5.13 cm, and armhole circumference 16.07 cm.

Remarkably, our analysis revealed that the 3rd work uniform, which garnered positive reviews for its movement suitability in a prior study [3], exhibited allowances above the average for all measured dimensions. This finding underscores the pivotal role of sufficient allowances in different sections during the pattern design phase, emphasizing a direct correlation with enhanced wearer comfort.

This exploration into dimensional allowances not only provides valuable insights into the specifics of winter coverall work uniforms but also contributes to the broader discourse on optimizing pattern design for functional and ergonomic benefits. The positive correlation identified, particularly exemplified by the 3rd work uniform, substantiates the significance of meticulous allowances in promoting optimal performance and comfort for individuals engaged in automotive maintenance tasks.

Pattern layout comparisons by section

This section delves into a meticulous examination of work uniform pattern layouts, employing the X-axis as the waistline and the Y-axis as the midpoint of the pants' inseam for consistent reference. Despite the uniform XL sizing of all six sets, our alignment within the YUKA CAD software unveiled noteworthy variations in length and angles across distinct sections.

Upon analyzing the pattern dimensions, we measured, several key observations emerged:

- Center Lengths: The 1st work uniform displayed the shortest front and back center lengths, contrasting with the 3rd work uniform, which showcased the longest measurements for these sections.
- Neck Circumference: The 5th work uniform boasted the largest front neck circumference, while the 3rd work uniform exhibited the smallest, with a reverse trend for back neck circumference.
- Chest Width: The 4th work uniform featured the broadest front chest width, whereas the 6th work uniform presented the narrowest. In terms of back chest width, the 3rd work uniform led as the largest, with the 2nd work uniform as the smallest.
- Waist Circumference: The front waist circumference reached its maximum in the 5th work uniform and minimized in the 6th work uniform, showcasing an opposite trend for back waist circumference.
- Shoulder Length: Shoulder length peaked in the 5th work uniform and reached its minimum in the 6th work uniform.
- Pants Length: Regarding pants length, the 1st work uniform emerged as the longest, while the 5th work uniform proved to be the shortest.

Most notably, the 3rd work uniform exhibited the lengthiest front and back crotch lengths, with a distinct angle apparent when aligning the front and back centerlines as the vertical reference. This distinctive observation implies that both crotch length and back center angle significantly contribute to facilitating freedom of movement, reinforcing the importance of these elements in optimizing work uniform design for enhanced practicality and comfort (Figure 2).

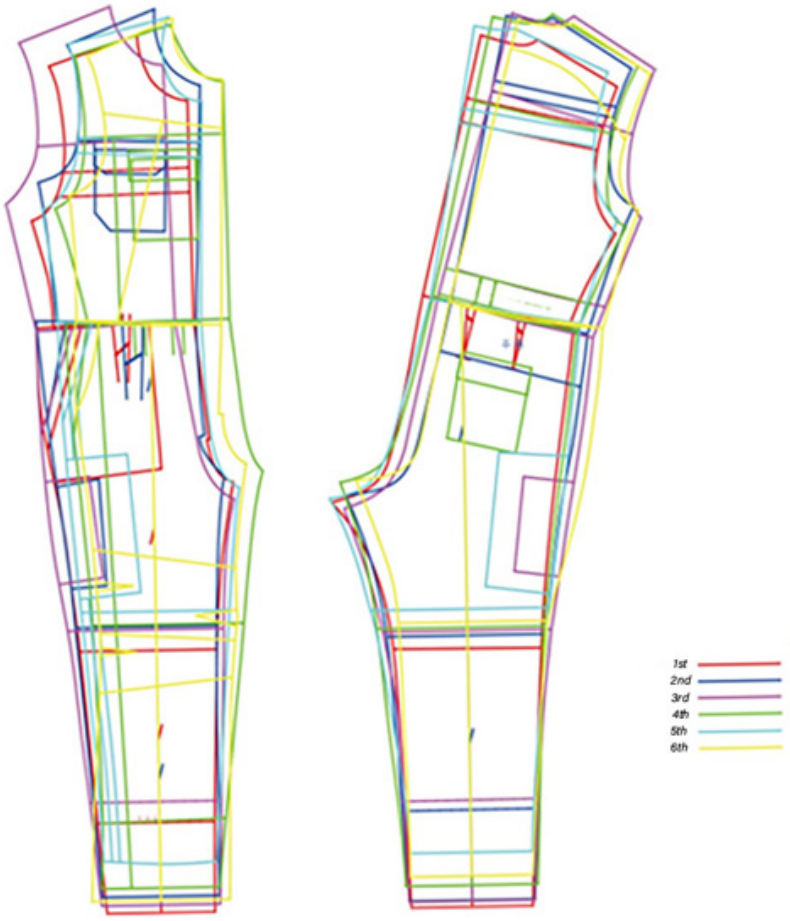


Figure 2: Pattern layout alignment compatibility.

Development of pattern and design for the 1st prototype work uniform

Development of the 1st prototype work uniform pattern: The formulation of the 1st prototype coverall works uniform pattern emanated from a thorough analysis, combining dimensions gleaned from the top-rated 3rd work uniform with design elements that had garnered commendable satisfaction in previous evaluations of diverse work attires. The endeavor to craft a unified coverall for both upper and lower body segments inherently necessitated considerations of movement impact on wear comfort, prompting the meticulous allocation of allowances for freedom of movement across diverse body regions.

Drawing upon insights from a prior study [4] that underscored the influence of back measurements on satisfaction during upper body movements, the 3rd work uniform emerged as the pivotal reference for the 1st prototype. The decision was fortified by the superior satisfaction linked to larger back measurements in the 3rd work uniform, accentuating the paramount role of these dimensions in optimizing wear comfort.

Although the 4th work uniform technically outstripped the 3rd work uniform in overall front and back measurements, the deliberate choice to design the 1st work uniform with a front measurement of 50.00 cm and a back measurement of 58.00 cm aligned with proven satisfaction levels associated with larger back measurements from the 3rd work uniform, as established in prior research [5].

The discernible difference between front and back dimensions significantly influenced neck and waist circumferences. Addressing challenges tied to the neck circumference of the 3rd work uniform, the 1st prototype incorporated adjustments, including a 1 cm reduction in the front neck point and a 0.5 cm extension of the side neck point.

Recognizing the impact of lower sleeve cap heights on arm mobility, the 1st prototype retained sleeve dimensions in harmony with the 3rd work uniform. The introduction of elbow darts, inspired by prior research studies [2,6-8] aimed to augment upper body functionality during maintenance tasks by facilitating increased freedom of movement.

Contrary to expectations, satisfaction evaluations suggested that the ease of the sleeve cap played a more significant role than the presence or absence of darts at the elbows. Therefore, the initial prototype's sleeve design aligned with the dimensions of the 3rd work uniform.

To enhance adjustability and ensure optimal comfort, the sleeve cuffs of the 1st prototype were thoughtfully designed with a two-layer approach. The outer layer was equipped with Velcro fasteners, allowing users to customize the fit according to their preference, thus enhancing overall comfort during wear and preventing potential discomfort. In a departure from the conventional treatment found in commercial work uniforms, the inner layer of the cuffs featured a ribbed design. This innovative approach not only aimed to provide effective insulation, especially in colder conditions, but also served as a protective barrier against contaminants like dust. The unique combination of Velcro fasteners and ribbed cuffs in the 1st prototype reflects a deliberate effort to offer a superior level of functionality and comfort, distinguishing it from traditional work uniform designs.

This design decision was informed by an evaluation of specific movements, including the 'maximum forward arm extension while standing (M4)' and 'maximum arm raising (M5)' actions. Notably, the 4th work uniform exhibited the highest satisfaction with sleeve cuffs during the former movement, while the 6th work uniform received favorable results for the latter. Considering these assessments, the sleeve cuff dimensions for the prototypes were meticulously patterned, allowing for a maximum extension of 33 cm when fully stretched and 18 cm for comfortable conditions.

The posterior waist region assumes a pivotal role in facilitating bending motions integral to various maintenance tasks, encompassing actions such as reaching arms forward, bending the back forward, or adopting crouched or seated positions. Recognizing the significance of this anatomical area, all six commercial work uniforms incorporate pleats designed to enhance flexibility and optimize work efficiency. These pleats are strategically oriented along the juncture connecting the upper and lower segments of the back waist, allowing them to dynamically expand lengthwise during periods of heightened activity, thus providing the necessary range of motion. Subsequently, these pleats contract to their original state when the wearer assumes an upright posture. To secure these pleats and ensure their functionality, elastic bands are employed along the inner side of the work uniform.

During a comprehensive evaluation encompassing various movements such as 'rising from a crouched position (M2),' 'bending the upper body forward 90 degrees (M3),' 'reaching arms forward as far as possible while standing (M4),' 'raising both arms as high as possible (M5),' and 'raising one knee and crouching while flexing the arms (M7),' the 3rd work uniform consistently garnered the highest satisfaction ratings. This commendation can be primarily attributed to the extended inseam length, which affords ample room for movement, a finding corroborated by previous research [9]. It is noteworthy, however, that an excess of surplus length in the rear rise has been associated with diminished overall satisfaction concerning appearance, aligning with established research [9]. External evaluations of the 3rd work uniform raised concerns regarding waistline positioning and overall fit.

In response to these valid concerns, an adaptation was introduced in the 3rd work uniform. This adaptation involved retaining an equivalent surplus length in the rear rise area, accompanied by the integration of enhanced pleats using elastic bands within the rear waist region. To address the identified issues, an additional surplus of 5 cm was incorporated by affixing three elastic bands, each with a 6 cm width, along the inner side of the rear waistline. These bands were strategically oriented diagonally, with an 11 cm separation between them. Furthermore, a 2.5 cm elevation was applied to the rear waist centerline. This adjustment aimed not only to mitigate the pressure exerted by the pull in the rear waist area during bending movements but also to elevate satisfaction with the garment's appearance in an upright posture.

The inclination angle of the rear centerline in pants is a critical factor influencing their appearance. When the angle is adjusted to incline towards the rear centerline, it tends to result in more favorable aesthetic evaluations. However, such an adjustment often leads to a shorter rear center length, which can have a detrimental impact on the functionality of the pants. Conversely, when the inclination angle is oriented towards the side seam, it increases the rear center length, thereby enhancing functionality. However, this adjustment may also introduce wrinkles in the lower buttock area, negatively affecting the overall aesthetic evaluation [10].

To establish the reference axis for determining the rear centerline, an arbitrary vertical line originating at the hip line and extending upwards is employed. When this line is used to measure the rear center in the 3rd work uniform, it is inclined at an angle of 15.7 degrees with a distance of 4.7 cm. Adjusting the rear centerline angle towards the rear direction, as per prior research by Kwon [11], eliminates superfluous fabric and mitigates wrinkles in the lower buttock region, resulting in a sleeker and more aesthetically appealing appearance. For pattern design, the rear center inclination angle was shifted by 1 cm towards the rear center, while retaining an overall surplus length at the rear. Additionally, an extra 0.5 cm extension was applied outward from the endpoint of the rear crotch to maintain the surplus length.

Prior research [8,12] suggests that introducing darts both above and below the knee centerline is recommended to alleviate discomfort associated with knee movement. However, a study by Ahn and Lee [5] found that the work uniform without darts, exemplified by the 3rd work uniform, outperformed the darts-incorporating version in both the upper and lower regions relative to the knee centerline, as shown by the 6th work uniform. This implies that the width of the pants' thighs and overall comfort play a more pivotal role in knee movement comfort than the presence or absence of darts during knee bending. Consequently, the experimental work uniform was crafted without darts in the knee area.

As for the pants cuffs, a common industry practice involves applying ribbed treatment to the lining for thermal insulation, extending down to the calf region and integrating with the outer layer. The

experimental work uniform adheres to this convention, featuring ribbed treatment in the lining of the pants cuffs for enhanced thermal insulation. In contrast, the outer layer is equipped with Velcro fasteners at the cuffs, providing adjustability to accommodate both thermal and comfort-related considerations.

Regarding the dimensions of the pants cuffs, the design was rooted in the measurements of the 3rd work uniform, specifying a width of 45 cm at maximum extension and 22 cm in an upright posture. Given that automotive maintenance activities often occur outdoors, requiring hoods for head protection, all six commercial work uniforms come equipped with detachable hoods. However, satisfaction evaluations revealed discomfort when wearers donned the hoods in an upright posture, exacerbated when participants manipulated the hood strings during work, negatively affecting the fit and appearance of the hoods.

To address these challenges, the hood pattern for the experimental work uniform was strategically modified, enlarging the hood width by 4 cm and extending the length by 5 cm, effectively mitigating discomfort associated with hood usage during work activities. The schematic representation of the pattern for the 1st prototype work uniform is visually depicted in Figure 3.

Design for the 1st prototype coverall work uniform

Material: The fabric employed in all six sets of work uniforms comprises an outer layer crafted from a P/C (Polyester 67% & Cotton 33%) twill weave. This outer layer is complemented by an inner lining featuring a 100% polyester twill weave material with a thickness of 7oz and a quilted Welron fiberfill.

Satisfaction assessments of conventional coverall work uniforms, specifically designed for winter, revealed various issues, such as susceptibility to staining and challenges associated with the thickness of the inner lining, hindering effective post-washing drying. In response, this study aimed to design work uniforms allowing the separation of the outer layer and inner lining to address washing versatility and adaptability to diverse work conditions and ambient temperatures.

For the outer layer, a P/C twill weave fabric identical to commercial work uniforms was selected. In contrast, the inner lining, which directly interfaces with the wearer's skin, featured an alternative, softer fabric. In line with prior research by Park [13], this inner lining was expertly fashioned from a P/C interlock knit fabric known for superior moisture-absorbing capabilities and a pleasingly soft tactile sensation. To enhance insulation, the inner lining underwent further quilting with 5oz of Welron fiberfill.

The decision to utilize a reduced weight of filling material in the experimental work uniform, relative to commercial counterparts, stemmed from the introduction of the inner lining, necessitating an additional fabric layer. This strategic choice aimed to mitigate unwarranted voluminosity in the experimental uniform, thereby averting potential confusion during subsequent appearance assessments. Both the thickness and weight of the filling material were carefully considered in determining the filling material weight.

Design features of the 1st prototype coverall work uniform

Integrated mobile phone pockets:

Drawing from the findings of Ahn and Lee [4], which identified a demand for mobile phone pockets, our design systematically integrates pockets into the upper sections of the sleeves. The dimensions are calibrated based on the largest mobile phone models available in the market, ensuring compatibility. Zippers on the sides of these pockets enhance practicality and allow for easy access. The design adopts a three-dimensional cargo style, optimizing storage, and includes a dual-purpose pen pocket above the mobile phone pocket.

Functional pocket configuration for pants:

The pants feature a functional pocket configuration, including front hip pockets and cargo pockets on both sides of the thigh area. To enhance user comfort, we deliberately increased the pocket openings by 1 cm on each side compared to standard pockets. This adjustment accommodates users, particularly when wearing gloves, a common practice during maintenance work.

Modular design with insulation elements:

The uniform adopts an integrated design for the outer shell and a modular approach for the inner lining, creating a two-piece structure. The upper garment of the inner lining connects to the outer shell at the neckline, while the lower part secures at the waist using 9mm-sized buttons and corresponding buttonholes. To augment insulation and protect against external elements, a 2x2 rib-knit fabric is implemented at the wrist and ankle regions of the inner lining.

Adjustability and comfort elements:

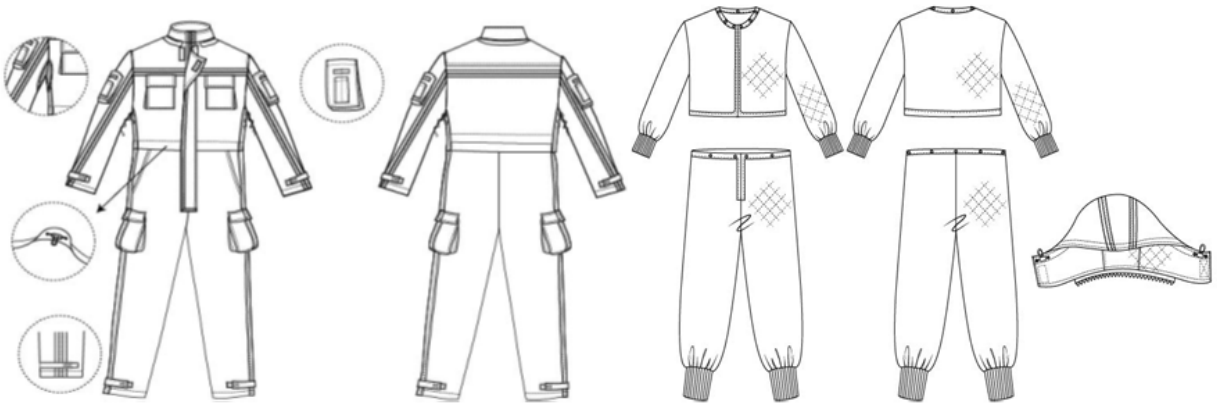
To facilitate size adjustment and prevent work materials from adhering to cuffs or sleeves, hook-and-loop fasteners (Velcro) are integrated into the outer shell. Waistline customization is achieved using a 3mm rounded elastic cord anchored with cord locks at the exterior waist. This design ensures efficient sweat management and enhances overall comfort during work. Additionally, the underarm area of the outer shell is fortified with a polyester mesh fabric, and a 5cm-wide strip of the same mesh material is horizontally incorporated across the back to promote increased airflow and freedom of movement.

Safety enhancement with retroreflective materials:

Ensuring worker safety during nighttime operations or within enclosed workspaces, retroreflective materials are strategically placed on specific areas, including the chest, back, side seams, and sleeves. Despite a limited preference for retroreflective elements in prior research [14], our design maintains a balanced approach, utilizing 3mm-wide piping for retroreflective detailing. This ensures improved visibility without causing excessive discomfort or inconvenience.

Visual representation:

Table 4: Flat scketchs and wearing photos of the 1st prototype work uniform.

Flat Sketches		
		
Front	Side	Back
		

Refer to Table 4 below for a detailed flat sketch of the prototype uniform, illustrating the integrated design and safety features discussed above.

Field suitability interview for the 1st prototype coverall work uniform

The findings from the on-site suitability interview with the sole participant, who wore the 1st prototype work uniform, are detailed below. Maintenance professionals predominantly work in outdoor settings, exposing them to direct climatic influences and potential hazards associated with vehicle and machinery servicing, including injuries from equipment and accidents involving contaminants.

Participant's aesthetic perceptions and fit satisfaction: Upon exploration of the aesthetic aspects of the experimental uniform, the participant expressed overall satisfaction, particularly

emphasizing comfort, and fit dimensions. Compared to traditional coverall work uniforms, the prototype was perceived as providing a more suitable level of roominess across various anatomical regions, thereby enhancing comfort during movements. Additionally, the participant praised the pleasant tactile qualities of the inner layer fabric and valued the versatility provided by the option to separate the layers for diverse applications during work activities.

Thickness and thermal insulation: The participant noted minimal discernible differences in thickness between the standard work uniform and the experimental uniform when worn. Furthermore, there was a lack of significant variance in thermal insulation. This observation aligns with theoretical research, suggesting that the thermal resistance of multiple fabric layers surpasses that of a single, denser fabric layer [12]. Consequently, the utilization of a separated inner layer is deemed more fitting for insulation purposes while concurrently enhancing laundering convenience.

These insights from the field suitability interview offer valuable perspectives on the adaptability, comfort, and functional attributes of the 1st prototype work uniform within the demanding outdoor work environment of maintenance professionals.

Evaluation of prototype work uniform by participant: In the context of a wearability experiment, the participant conducted a comprehensive assessment of the prototype work uniform, providing pertinent observations and constructive recommendations:

1. **Fit and adjustment:** The initial impression of an oversized fit raised concerns about sizing, mitigated successfully through adjustments using the waistband. Subsequently, the uniform provided notable roominess and comfort during various movements, surpassing initial apprehensions.
2. **Thermal insulation**: Despite its modest thickness, the prototype exhibited commendable thermal insulation, deviating notably from conventional coverall work uniforms characterized by bulkiness and weight.
3. **Layer separation and inner layer comfort**: The practicality of separating outer and inner layers for specific applications during work was underscored as advantageous. The perceived softness of the inner layer fabric against the skin was appreciated, though extended use raised concerns about warmth and shoulder strain.

Participant's design feedback: The participant's insights into the design of the work uniform included recommendations and observations on various elements:

- Retro-Reflective Material: Commending the incorporation of retro-reflective material, the participant suggested expanding its surface area to augment safety features, especially in low-light environments.
- Safety Concerns: A safety hazard related to the positioning of the waist strap was identified, presenting potential entanglement risks during typical maintenance activities.
- Minor Discomforts: The participant highlighted discomforts related to the neck area button and uneven Velcro lengths, emphasizing their inconvenience during work. Additionally, concerns were raised about the mesh material compromising insulation.
- Pocket Design: The placement of the pocket with a side zipper on the arms was questioned, expressing concerns about the security of items during work activities.
- Overall Satisfaction: Despite these observations, the participants generally expressed satisfaction with other components and fasteners, indicating alignment with expectations and requirements.

These insights, rooted in the participant's direct experience, provide valuable guidance for the iterative refinement and optimization of the prototype coverall work uniform design. The participant's feedback underscores the significance of considering safety, functionality, and comfort in the design of industrial work uniforms, especially for individuals engaged in diverse industrial settings.

Final coverall works uniform pattern develop and design

Final coverall works uniform pattern development: Following an initial assessment of the experimental uniforms and meticulous consideration of feedback from an auto mechanic maintenance participant, iterative adjustments were made to refine the pattern design and the overall coverall design. While the first-phase experimental uniform garnered higher satisfaction levels in on-site suitability interviews compared to existing commercial uniforms, discernible areas meriting refinement were identified. To specifically address reported discomfort associated with fully zipping up the front zipper to the neck, targeted modifications were implemented for the final coverall work uniform:

- Collar Height Reduction: The collar height of the first-phase experimental uniform was systematically reduced from 9cm to 5cm.
- Front Neckline Deepening: A deliberate deepening of the front neckline by 1cm was executed.
- Side Neckline Depth Increase: Incremental increments, specifically 0.5cm on each side, were applied to increase the depth of the side neckline (Figure 4).

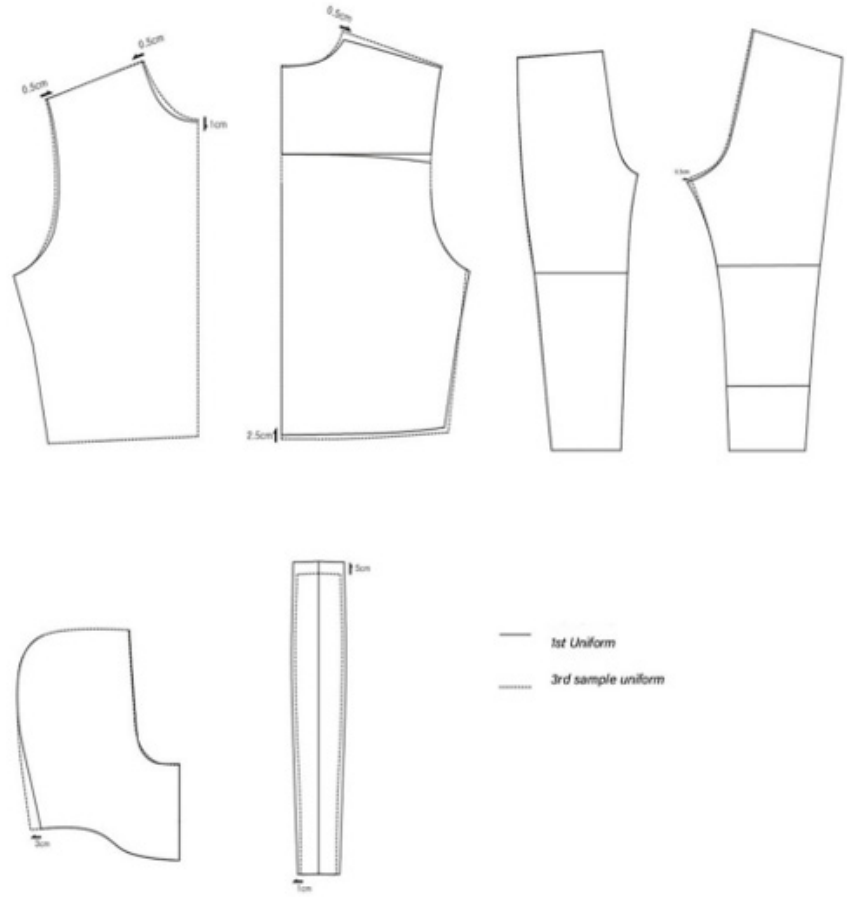


Figure 3: 1st prototype coverall uniform pattern development.

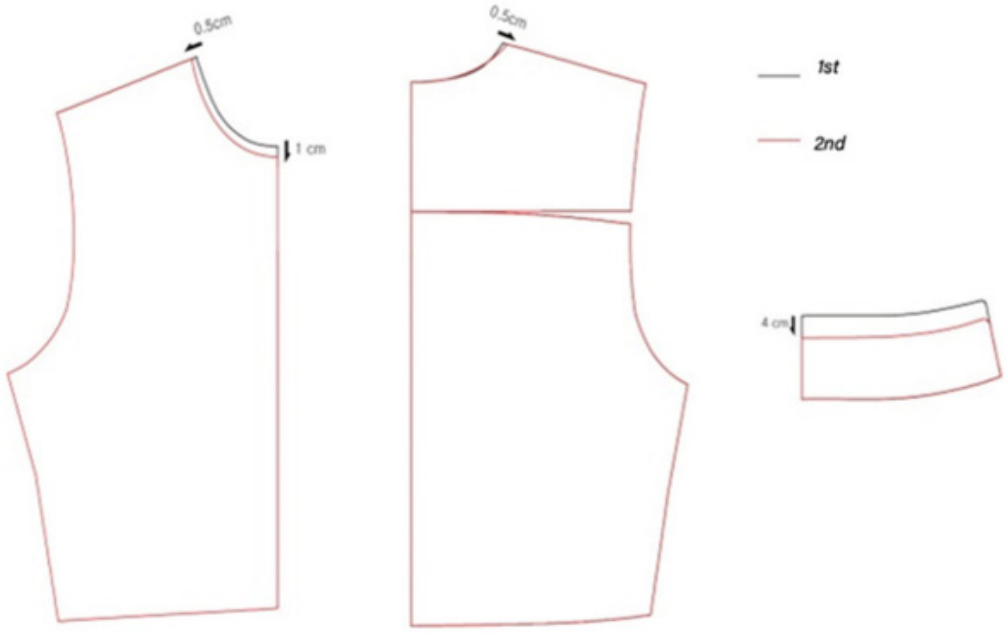


Figure 4: Modified Prototype Coverall Uniform Pattern Development.

These meticulous adjustments were aimed at elevating overall comfort and addressing specific concerns articulated during the wearability experiment.

Final coverall works uniform design: After a comprehensive evaluation of the initial prototype for the experimental coverall work uniform, participant feedback revealed no discomfort during static postures in the lower part of the uniform. However, discomfort arose during actual work movements, particularly related to the buttons at the juncture of the outer fabric and lining of the upper garment, causing undue pressure on the neck. To rectify this, adjustments were made in the design of the first-phase experimental uniform. Buttons were relocated to the inner circumference of the outer fabric's collar, and elasticized buttonholes were incorporated into the lining's collar, effectively eliminating direct button contact with the neck.

Feedback also highlighted concerns about cold air ingress in the underarm area, compromising thermal insulation and overall comfort. In response, concealed zippers were introduced in this region, providing adjustable ventilation as needed.

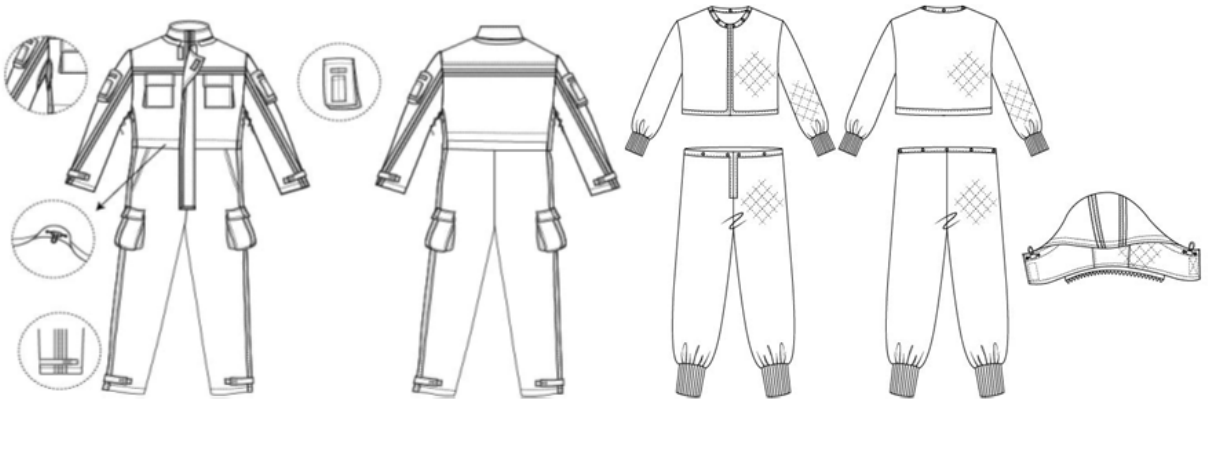
Addressing input on reflective piping, the width was increased from 3mm to 1cm. This modification, influenced by both personal preferences and the critical need for enhanced workplace visibility, aligns with safety considerations.

Regarding the waist size adjustment string, the initial design aimed to prevent the string's end from protruding outward. However, concerns arose about the cord lock's location on the outer surface of the waist, potentially causing discomfort and safety hazards. Consequently, the cord lock was repositioned to the inner surface of the waist flap, ensuring no external protrusion.

While the placement of the mobile phone pocket was generally satisfactory, feedback raised concerns about the side zipper's location, posing a risk of the phone falling out during work. To enhance security, the zipper was relocated to the top of the pocket.

As for the hat of the first-phase experimental coverall work uniform, an increase in size aimed at reducing discomfort resulted in lower overall satisfaction in terms of appearance. To address this, the design was refined based on a prior study [15], involving the elimination of darts on the collar circumference and the introduction of a 5cm slope on the collar circumference. This resulted in a more comfortable and aesthetically pleasing final coverall work uniform.

The flat scketchs and wearing photos of the modified final coverall work uniform can be found in Table 5.

Flat Sketches		
		
Front	Side	Back

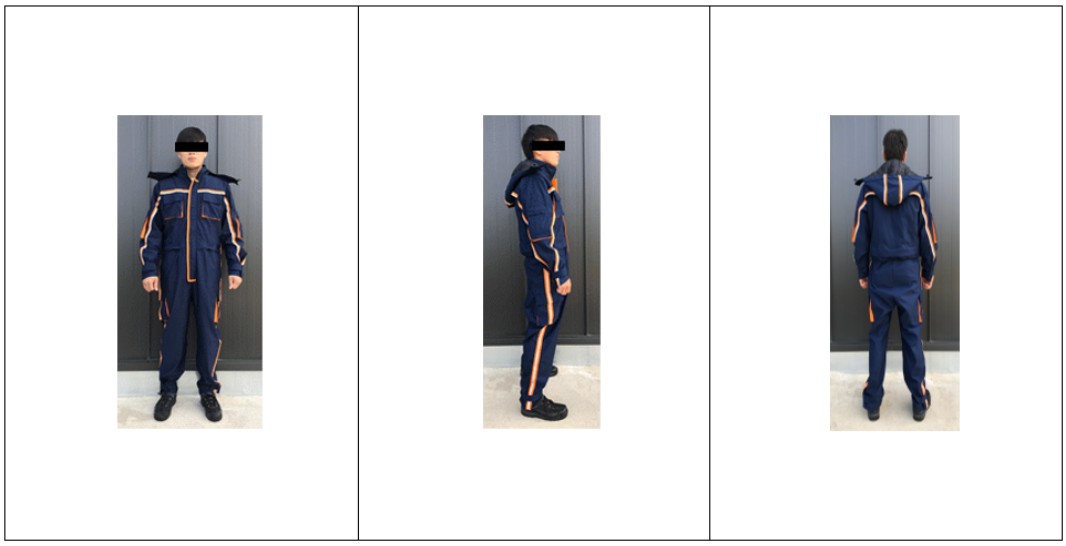


Table 5: Plat scketchs and wearing photos of the final coverall work uniform.

Conclusion and Recommendations

This study represents a comprehensive exploration into the creation of a winter-oriented, coverall workwear solution tailored explicitly for automotive mechanics. Our primary goal was to develop a coverall work uniform that effectively addresses the challenges prevalent in the automotive repair industry. Our investigation involved a thorough analysis of existing coverall work uniform offerings from Korean manufacturers, complemented by on-site assessments involving automotive mechanics. The culmination of these efforts resulted in the refinement of a pattern and design for the ultimate coverall work uniform.

Conclusions and implications

Summary of findings: Our examination of winter coverall workwear patterns from Korean manufacturers revealed significant dimensional variations, emphasizing the need for personalized sizing considerations. Critical insights emerged regarding dimensional allowances in workwear patterns, highlighting the importance of adequate allowances to enhance wearer comfort and facilitate movement during automotive repair activities. Notable differences between front and back panel dimensions underscored the necessity for meticulous design considerations.

On-site suitability interviews: Positive feedback from on-site interviews underscored the effectiveness of the first-phase uniform in terms of flexibility, separability of layers, lightweight design, and insulation properties. However, concerns regarding certain aspects, such as the protrusion of the waist adjustment string and the balance between breathability and insulation due to mesh material, were raised. Suggestions for modifications were noted, including adjustments to button placement, Velcro tape sizes, and the entrance of the mobile phone pocket.

Refinement of experimental uniform: The refinement phase, informed by insights gleaned from on-site interviews, resulted in significant enhancements to the final work uniform design. Modifications addressed comfort-related issues associated with the front zipper and hat, including alterations to collar height, neckline depth, and hat pattern. Additionally, adjustments were made to button and buttonhole positions, underarm mesh design, retroreflective material width, and waist adjustment string placement, aiming to optimize practical usability.

Limitations: Acknowledging the limitation of a relatively small sample size, primarily comprising automotive mechanics specializing in maintenance work, the generalizability of findings may be constrained. Nonetheless, this research provides a foundational framework for future studies focusing on tailoring coverall work uniforms to the specific needs of automotive mechanics.

Future recommendations: Future research endeavors can build upon the developed patterns and designs to further refine and expand the scope of coverall work uniforms for automotive mechanics. Enhancing the generalizability of findings through a larger and more diverse sample, along with collaboration with industry stakeholders and manufacturers, can facilitate the practical implementation of the developed coverall work uniform in automotive repair settings.

Conclusion

In conclusion, this research significantly contributes to improving workplace conditions for automotive mechanics in South Korea, laying the groundwork for future endeavors in the domain of tailored workwear solutions.

Acknowledgement

None.

Conflict of Interest

Authors declare no conflict of interest.

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